Abstract

Electromagnetics find wide applications in the area of melting, handling and heating of metals. The major advantage is the application of heat or force without contamination. This thesis presents the design, fabrication and evaluation of an electromagnetic stirrer. Such stirrers find application in stirring the molten metal during the freezing phase of ingot making.

The microstructure of the material plays an important role on the physical properties of the metal. The microstructure in turn depends on the history of freezing during the forming process. Several methods to get different micro-structures in metals are being employed - some of them mechanical. A more popular and convenient method to achieve the same is through electromagnetic stirring.

The desired force in the metal is produced through electromagnetic induction. An alternating field is setup in the molten metal. The resultant eddy currents interacting with the field produce mechanical forces in the metal. The magnitude of the forces produced and the depth of penetration of the same are related to the magnetic field and the frequency. The design of such stirrer is quite challenging on account of several trade-offs involved. On account of large currents involved, the thermal design poses several challenges as well.

In the process of ingot casting, stirring can be introduced in the transverse or tangential direction. Accordingly the stirrers are classified as linear or rotary. A linear stirrer uses traveling magnetic field whereas a rotary stirrer uses rotating magnetic field to produce swirling action in the metal pool.

Figure 0.1 shows the structure of a linear electromagnetic stirrer. The principle of working is similar to that of a linear induction motor. When the space displaced coils $(AA^{'}, BB^{'}, CC^{'})$ are excited by three phase currents, a traveling magnetic field is established along the axis of the coils. The axial field is varying with time. This varying axial field produces induced

voltage in the molten metal in the tangential direction. The eddy current in the liquid metal and the magnetic field produce forces in the liquid metal. These forces will be predominantly in the axial direction and partly in the radial direction. These forces set the liquid metal into motion. Strong melt flow will result in strong shear stresses at the liquid-solid boundary of the ingot. This shear force alters the microstructure favorably. The resulting microstructure - free from dendrites - is well suited for semi-solid forming process in the fabrication of several components. In the above process, stirring the molten metal during solidification is achieved by electromagnetic means.

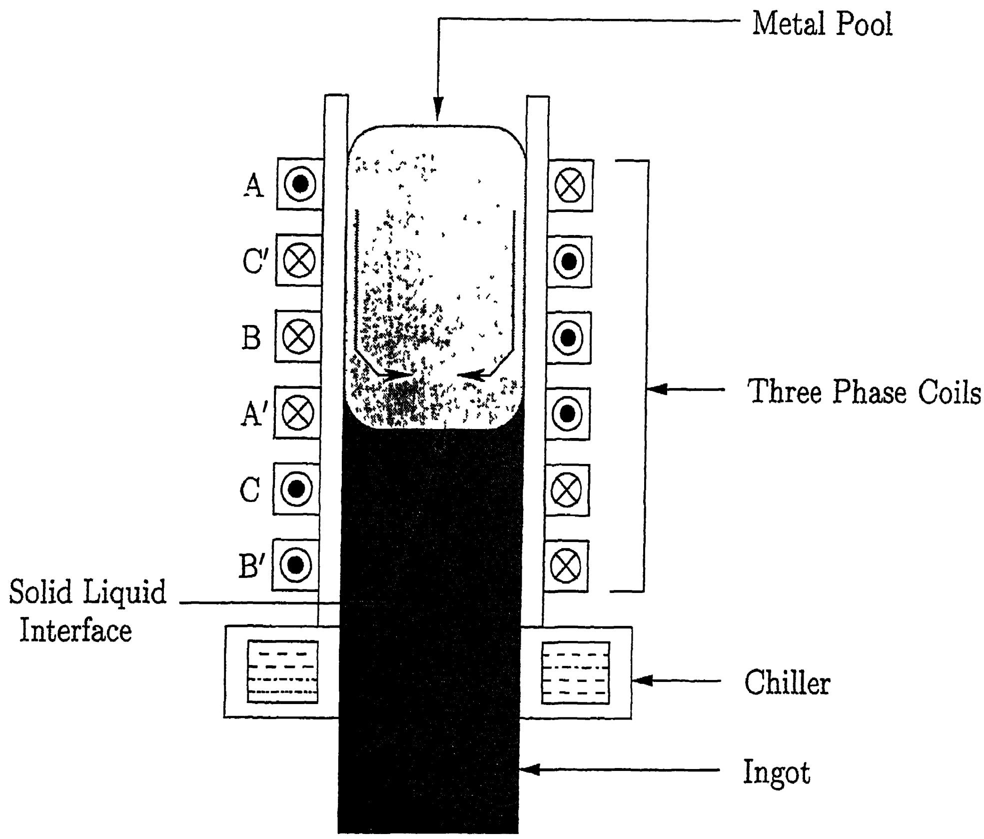

Fig. 0.1: Structure of a 2-pole Linear Electromagnetic Stirrer

An experimental prototype is fabricated to validate the design and its performance is evaluated. Results obtained from mathematical model, numerical model and the prototype are presented.